KEY PARAMETERS FOR EXTRUDED DC CABLE QUALIFICATION

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ABSTRACT

Electricity consumption increase, difficulties to built new lines and improvements on electronic components contribute to make DC solutions really attractive. The aim of this study is to identify keys parameters which impact polymeric DC cable ageing. Thermal and electric field distribution, mechanical stresses and space charge accumulation strongly impact DC cable behaviour and are not take into account in DC qualification process. Investigations are needed to improve qualification tests both for new DC cable and AC cable dedicate to operate in DC. Analysis of AC underground cable up-rating shows the complexity of this solution, demonstrate the necessity to work on qualification processes and DC ageing law.

KEYWORDS

HCDC cable, Qualification test, Space charge. Up-rating

INTRODUCTION

Transmission grids are not well accepted by the public, particularly overhead lines that are mainly accused their lack of discretion into the landscape. To face this collective demand, the main challenges for TSOs are to:

- increase as far as possible the existing grid ampacity,
- take into account all the available technologies to create new links, even if the investment cost is higher, and take care with environmental issues,
- be able to connect to the transmission grid new suppliers (off-shore wind farms or else),
- contribute to the energy market deregulation and to the European grid well-balancing, by creating long interconnections, often based on DC solutions.

As many improvements on electronic components and associated hardware arrangement have been performed during the last decade, DC solutions are today really attractive. Power density and locking voltage are key points in reducing conversion losses, decreasing converters size, and contributing to secure converter stations in operation. New solutions for these issues do really exist and should allow the increase HVDC links efficiency in the next decade.

Polymeric insulation into DC cable appears to be a key point. As the temperature core can reach 70℃ for synthetic insulation, meanwhile it is limited to 55℃ for mass impregnated paper, the ampacity can be increased (about 8-10%).

In an other way, for the same power, the core section can be reduced by about 16% with a polymeric insulation, compared to a mass impregnated one. This advantage also means that the diameter of the other layers can be reduced: insulation, screen, sheath, armour for submarine cables. It can be expected that the cable is about to be significantly reduced as well as associated laying conditions costs.

Unfortunately, such cables can suffer from the following:

- a non-linear distribution of the DC electric field through the insulation, depending on the temperature and finally on the cable load.
- a limitation of the dielectric withstand due to space charge, particularly in case of fast voltage inversion.

For these reasons, HVDC projects with extruded DC cable are limited to voltages below 320 KV for the moment.

The first part of the paper will introduce the different parameters which impact the behaviour and the ageing process of extruded DC cable. Influence of temperature on electric field distribution and space charge contribution will be more particularly described. Then, a discussion about qualification process of extruded DC cable according to CIGRE TB 219 [1] will be done. The analysis of qualification process taking into account new possible criteria for such cables will be suggested. Some improvements of the qualification process are suggested, particularly about the electrical long time duration test and the associated power law. The last part of the paper will deal with extruded designed AC cables in DC applications. The behaviour of AC insulation with DC stresses will be drawn up and the interest of this solution will be detailed.

INFLUENTIAL PARAMETERS FOR EXTRUDED DC CABLE AGEING

Electric field distribution in DC cable insulation

Differences between AC and DC field calculation in insulation cables are well known. The calculation of electric field distribution in AC cables depends on the permittivity of the insulation material, on the cable geometry and on the applied voltage. The temperature effect on permittivity, and consequently on the electric field, is negligible. Thus, the electric field distribution, at any radius r, is given by equation [1]:

$$E(r) = \frac{V}{r \cdot \ln\left(\frac{r_2}{r_1}\right)} \qquad [1]$$

Where *E(r)* is the electric field at radius *r*; *V* is the AC voltage, r_1 is the cable insulation inner radius and r_2 is the cable insulation outer radius.

As the electrical resistivity of insulation material is highly linked to temperature and local electric field under DC conditions, the calculation of electric field distribution is more complex in DC. The two main expressions used in the literature to describe the conductivity are given by equations [2] and [3]. The first relation is developed for mass-impregnated insulations but may be used for